

Original Research Article

Carbapenemase-producing *Enterobacteriaceae* and *Acinetobacter* species among pregnant women in Rivers State, Nigeria

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Abstract

Purpose: To investigate the prevalence, antibiotic resistance profiles, and carbapenemase production among *Enterobacteriaceae* and *Acinetobacter* spp. isolated from pregnant women attending selected tertiary hospitals in Rivers State, Nigeria.

Methods: This is a cross-sectional study conducted from April to December, 2024, in the University of Port Harcourt Teaching Hospital (UPTH), Rivers State University Teaching Hospital (RSUTH), and Madonna University Teaching Hospital (MUTH). A total of 423 midstream urine samples were collected from consenting pregnant women. The isolates obtained from the urine samples were identified using standard morphological and biochemical procedures. Antimicrobial susceptibility was determined using modified Kirby-Bauer method and interpreted using CLSI standards, while the carbapenemase production was confirmed phenotypically using the Modified Hodge Test (MHT), Triton Hodge Test (THT), and Modified Carbapenem Inactivation Method (mCIM).

Results: The 423 samples yielded 170 isolates, including 165 *Enterobacteriaceae* and 5 *Acinetobacter* spp. High level of resistance was observed against β -lactam antibiotics, while fluoroquinolones showed moderate activity. The majority showed imipenem resistance and were phenotypically confirmed as *Klebsiella pneumoniae* carbapenemase or metallo- β -lactamase producers. No significant association ($p > 0.05$) was observed between isolate distribution and demographic factors.

Conclusion: The detection of multidrug-resistant (MDR) and carbapenemase-producing *Enterobacteriaceae* and *Acinetobacter* spp. among pregnant women in Rivers State emphasises the need for antimicrobial stewardship and molecular surveillance programmes.

Keywords: *Enterobacteriaceae*, *Acinetobacter* spp., Antibiotic resistance, Carbapenemase, Pregnant women, Metallo- β -lactamase, *Klebsiella pneumoniae*

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INTRODUCTION

Gram-negative bacteria, particularly Enterobacteriaceae and Acinetobacter spp., pose a significant threat to human health due to high rate of developing antimicrobial resistance [1]. These organisms are implicated in a wide range of infections, including urinary tract infections (UTIs), wound infections, and neonatal sepsis in vulnerable groups. Physiological and immunological changes during pregnancy, such as alterations in hormone levels, urinary stasis, and immune modulation, predispose women to microbial colonisation and infection. While many infections during pregnancy may remain asymptomatic, resistance and Gram-negative pathogens increase the risk of preterm labour, maternal sepsis, and perinatal morbidity [2].

Carbapenemase-producing bacteria, particularly KPC and NDM variants, have rendered treatment options very limited. These enzymes inactivate most β -lactam antibiotics, which include carbapenems [3]. In Nigeria, the prevalence of carbapenem-resistant Enterobacteriaceae and Acinetobacter spp. has been reported in several studies, mainly due to the indiscriminate use of antibiotics and poor infection prevention and control measures [4]. However, there is a limited number of studies on the prevalence and resistance mechanisms for carbapenem resistance among pregnant women in Rivers State. Most studies have focused on general hospital populations or non-pregnant cohorts [5]. Given the risk associated with indiscriminate use of antibiotics during pregnancy, the study of local resistance profiles is imperative to guide appropriate therapeutic options.

Antimicrobial resistance (AMR) has emerged as a critical global health threat, with Gram-negative bacteria such as Enterobacteriaceae and Acinetobacter spp. driving severe infections that are increasingly difficult to treat [6]. Pregnant women represent a particularly vulnerable population due to physiological and immunological changes that predispose them to microbial colonisation and infection, which results in complications, including preterm labour, maternal sepsis, and perinatal morbidity [7]. The recent emergence of carbapenemase-producing organisms such as KPC and NDM variants has also put further limitations on the treatment options by hydrolysing all classes of β -lactam antibiotics, including carbapenems. In Nigeria, an increase in the incidence of carbapenem-resistant Gram-negative pathogens has been attributed to the indiscriminate use of antibiotics and poor infection control practices [8]. However, there is a knowledge gap regarding the

prevalence, antimicrobial susceptibility, and resistance mechanisms of these pathogens among pregnant women in Rivers State. Without evidence-based information on the pattern of resistance among pregnant women, management of the infections is precarious.

This study is aimed at isolating and characterising Enterobacteriaceae and Acinetobacter spp. from pregnant women attending tertiary health-care facilities in Rivers State, Nigeria, as well as evaluating antimicrobial susceptibility profiles and detecting phenotypic carbapenemase producers. The results of this study would be an addition to the knowledge of resistance patterns among this population and would be useful in the formulation of rational antibiotic policies.

EXPERIMENTAL

Study area

The study location is Rivers State, one of the six states in the South-South geopolitical zone of Nigeria. The state is surrounded by Imo, Abia, and Anambra States, Akwa Ibom, Bayelsa and Delta State. Rivers State spans approximately 11,077 square kilometres. The population is estimated at a million people [9]. The state capital is Port Harcourt, located at latitude 4°45'N and longitude 6°50'E. The location is in the Niger Delta, characterised by extensive river networks, swamps, and creeks.

Study population and sample size

The study enrolled pregnant women aged 15 - 49 years attending the selected antenatal clinics. The age range was selected as it represents the standard reproductive age in females [8]. Using Cochran's formula for cross-sectional studies, the calculated minimum sample size of 352 was based on a prevalence rate of 29.5 % and adjusted for a 10 % non-response rate. However, a total of 423 urine samples were collected from participants across three tertiary hospitals: University of Port Harcourt Teaching Hospital (UPTH, n = 168), Rivers State University Teaching Hospital (RSUTH, n = 155), and Madonna University Teaching Hospital (MUTH, n = 100). Sample allocation was proportional to the antenatal clinic attendance rate of each hospital.

Study design and sampling technique

A cross-sectional hospital-based study was conducted for a period of eight months (April-December 2024) in the selected three tertiary

hospitals. Using convenience sampling, participants were enrolled in the study based on eligibility and informed consent. Data on socio-demographic characteristics and clinical history were obtained using a structured, self-administered questionnaire.

Ethics approval and consent to participate

Ethical approval was obtained from the Research Ethics Committees of the participating hospitals (UPT/ADM/90/S.II/VOLXI/1718; MAU/DRC/HD/E/2024/008; NHREC/21/033/2022). Participation was voluntary, with informed written consent obtained from all subjects. Confidentiality and data privacy were strictly maintained.

Inclusion and exclusion criteria

Inclusion criteria were pregnant women aged 15 – 49 years who were willing to participate in the study. Specifically excluded from this study were vulnerable women, those who had severe illness or mental disorders, renal diseases, and incomplete demographic information, and those currently on antibiotic therapy or who had taken antibiotics within 72 hours of specimen collection.

Research instrument, validity, and reliability

The data were collected using a structured questionnaire with two sections: Section A includes information on the socio-demographic data, and Section B includes information on the clinical history. The instrument of data collection was validated for relevance to the study objectives by a clinical pharmacist from Madonna University, Elele, Nigeria. Reliability testing was done using Cronbach's Alpha in the course of a pilot study. A coefficient of ≥ 0.70 was considered acceptable, indicating good internal consistency.

Sample collection and processing

Midstream urine samples (10 – 20 mL) were aseptically collected in sterile containers from consenting participants, excluding those who met exclusion criteria. The samples were immediately labelled and inoculated into nutrient broth for pre-enrichment and incubated at 37 °C before culture.

Bacteriological culture and identification

The cultures were done on Eosin Methylene Blue (EMB) and Cysteine-Lactose-Electrolyte-Deficient (CLED) agar plates by conventional loop inoculation techniques of Thapa et al [10].

The incubation was done at 37 °C for 18 – 24 hours. Colonies were identified by colony morphology as follows: the colonies of lactose-fermenting Enterobacteriaceae appeared purplish-pink on EMB (with *E. coli* showing a metallic sheen), whereas the Acinetobacter colonies were pale, translucent, and non-lactose fermenting. Gram staining and biochemical tests, including catalase, oxidase, and indole reactions, were done for the confirmation of identification.

Antimicrobial susceptibility testing

Antimicrobial susceptibility testing (AST) was carried out using the modified Kirby-Bauer disc diffusion method on Mueller-Hinton agar according to CLSI standards. The bacterial cultures were first standardised to a 0.5 McFarland turbidity and then inoculated on agar plates and incubated at 37 °C for 16 – 18 hours. Zones of inhibition were recorded and interpreted according to CLSI/EUCAST standards [11]. The antibiotics used in this study include amoxicillin-clavulanate, cefotaxime, imipenem, ofloxacin, gentamicin, nalidixic acid, nitrofurantoin, cefuroxime, ceftriaxone-sulbactam, ampiclox, cefixime, and levofloxacin.

Determination of multidrug resistance

Calculation of the Multiple Antibiotic Resistance Index (MARI) to determine multidrug resistance was carried out using Eq 1.

$$\text{MARI} = a/b \dots\dots\dots (1)$$

where a is the number of antibiotics to which an isolate is resistant, and b is the total number tested [8].

Screening and confirmation of carbapenemase production

Confirmation that carbapenemase production was achieved by the use of using the Modified Hodge Test (MHT), Triton Hodge Test (THT), and Modified Carbapenem Inactivation Method (mCIM) following the recommendations of the Clinical and Laboratory Standards Institute (CLSI). The MHT results confirmed the presence of a cloverleaf indentation of the indicator strain (*E. coli* ATCC CP184077.1) along the streak line. For THT, the addition of 1 % Triton X-100 increased the sensitivity of the test for the detection of the carbapenemase enzyme. The mCIM was interpreted as positive when the inhibition zone was ≤ 15 mm [3]. Further differentiation between *Klebsiella pneumoniae* (KPC) and

metalloβ-lactamase (MBL) production was achieved using inhibitor-based combined-disc assays, while an increase of ≥ 5 mm in inhibition zone with phenylboronic acid (PBA) indicated KPC activity, while an increase of ≥ 5 mm with EDTA indicated MBL activity [12].

Statistical analysis

The analysis of the results was done using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to analyse the demographic and clinical information, while Chi-square (χ^2) test was used to analyse the associations between categorical variables and bacterial isolates. Statistical significance used in the analysis was set at $p < 0.05$.

RESULTS

Demographic and clinical characteristics of the population

The results indicate that there were no statistically significant differences ($p < 0.05$) in

the distribution of participants across the variables considered (Table 1).

Distribution of bacterial isolates across demographic and clinical spread

The distribution of Enterobacteriaceae and *Acinetobacter spp.* Isolates among pregnant women showed a higher occurrence of *Enterobacteriaceae* in the three tertiary health institutions (Table 2). This illustrated the correlation of the prevalence of these bacterial isolates with various demographic and obstetric factors such as age, gestational age, educational level, and parity. The association between the prevalence of MDR Enterobacteriaceae and *Acinetobacter spp.* isolates and key demographic and clinical characteristics of the study population revealed important heterogeneity in MDR distribution across hospitals and maternal populations. The MDR *Acinetobacter spp.* were more prevalent in RSUTH and MUTH, while MDR Enterobacteriaceae were more prevalent in UPTH. The result recorded increased MDR isolates among participants of higher age and lower education.

Table 1: Demographic information of the respondents

Parameter	Distribution (%)	Chi-square (p)
Facility		
UPTH	168 (39.71)	(χ²): 4.32 (p): 0.1152
RSUTH	155 (36.64)	
MUTH	100 (23.64)	
Total	423(100 %)	
Age		
≤ 20 years	45 (10.63)	(χ²): 0.78 (p): 0.0792
21-30	151 (35.69)	
31-40 years	138 (32.62)	
> 40 years	89 (21.04)	
Total	423(100 %)	
Gestation weeks		
≤ 12 weeks	57 (13.47)	(χ²): 2.21 (p): 0.531
13-27 weeks	112 (26.47)	
28-40 weeks	189 (44.68)	
> 40 weeks	65 (15.36)	
Total	423(100 %)	
Highest education level		
No Formal Education	143 (13.40)	(χ²): 1.99 (p): 0.574
Basic School Level	39 (9.20)	
Secondary school level	57 (33.80)	
Tertiary Level	184 (43.49)	
Total	423(100 %)	
Number of pregnancies		
1	148 (43.49)	(χ²): 3.67 (p): 0.146
2–4	221 (52.24)	
≥5	54 (12.76)	
Total	423(100 %)	

Table 2: Correlation between the isolates and demographic and clinical parameters

Parameter	Total isolates			Total MDR isolates		
	E _{occ} (%)	A _{occ} (%)	Z	E _{occ} (%)	A _{occ} (%)	Z
Facility						
UPTH	64(38.79)	0(0.00)	$\chi^2 = 3.28$ $p = 0.194$	51(50.00)	0(0)	$\chi^2 = 4.81$ $p = 0.090$
RSUTH	53(32.12)	3(60.00)		29(28.43)	3(60.00)	
MUTH	48(29.09)	2(40.00)		22(21.57)	2(40.00)	
Age (years)						
≤ 20	17(10.30)	1(20.00)	$\chi^2 = 2.00$ $p = 0.572$	12(11.76)	1(20.00)	$\chi^2 = 1.91$ $p = 0.592$
21-30	43(26.06)	2(40.00)		26(25.49)	1(20.00)	
31-40	40(24.24)	0(0.00)		23(22.55)	0(0)	
> 40	65(39.39)	2(40.00)		41(40.00)	3(60.00)	
Gestation weeks						
≤ 12	16(9.70)	1(20.00)	$\chi^2 = 3.30$ $p = 0.347$	11(10.78)	1(20.00)	$\chi^2 = 3.98$ $p = 0.263$
13-27	48(29.09)	2(40.00)		24(23.53)	2(40.00)	
28-40	64(38.79)	0(0.00)		46(45.10)	0(0)	
> 40	37(22.43)	2(4.00)		21(20.59)	2(40.00)	
Highest education level						
No formal education	53(32.12)	3(60.00)	$\chi^2 = 3.67$ $p = 0.299$	32(31.37)	3(60.00)	$\chi^2 = 3.75$ $p = 0.290$
Basic school level	20(12.12)	1(20.00)		14(13.73)	1(20.00)	
Secondary school level	22(13.33)	1(20.00)		12(11.76)	1(20.00)	
Tertiary level	70(42.42)	0(0.00)		44(44.14)	0(0)	
Number of pregnancies						
1	67(40.61)	1(20.00)	$\chi^2 = 2.74$ $p = 0.254$	45(44.12)	1(20.00)	$\chi^2 = 3.60$ $p = 0.166$
2-4	72(43.64)	4(80.00)		39(38.24)	4(80.00)	
≥ 5	26(15.76)	0(0.00)		18(17.65)	0(0)	

E_{occ} (Occurrence of Enterobacteriaceae), A_{occ} (Occurrence of *Acinetobacter* spp), Z (χ^2 Chi-square p -value)

Antibiotic resistance patterns of bacterial isolates

The antibiotic resistance patterns of the suspected *Escherichia coli*, *Klebsiella pneumoniae*, and *Acinetobacter* spp among pregnant women in three tertiary hospitals indicated a widespread resistance (>50 %), particularly for *K. pneumoniae* and *Acinetobacter* spp to β -lactams (amoxicillin-clavulanate and ampiclox), imipenem/cilastin, gentamicin, cefixime and ceftriaxone. at the UPTH (Figure 1 A). High resistance of the isolates to amoxicillin-clavulanate, ampicillin, imipenem/cilastin, nitrofurantoin and cefuroxime was recorded at UPTH (> 50 %; Figure 1 B). However, at the MUTH, all the isolates had high resistance to imipenem/cilastin, ampiclox and cefixime at the MUTH (Figure 1 C).

Distribution of MDR isolates in clinical samples

The distribution of MDR Enterobacteriaceae and *Acinetobacter* spp. Isolates obtained from clinical urine samples of pregnant women attending antenatal clinics provided a detailed list of bacterial isolates with the corresponding multiple antibiotic resistance index (MARI) values (Figure 2). A MARI > 0.20 indicates a high-risk source of contamination due to frequent and/or inappropriate use of antibiotics. Suspected isolates of *E. coli*, *K. pneumoniae* and

Acinetobacter spp possessed high MARI values, with some MARI $\approx$ 1.0.

Bacterial isolates as carbapenemase producers

The results of the carbapenemase-producing potential of the isolates showed the prevalence of carbapenemase producers in 54 (32.73 %) isolates out of the 165 Enterobacteriaceae isolates screened. with the highest frequency in RSUTH (17.58 %), followed by MAUTH (10.91 %) and UPTH (4.24 %; Table 3). All the *Acinetobacter* spp isolates screened were carbapenemase producers (100 %).

Table 3: Carbapenemase-producing isolates

Facility	Enterobacteriaceae (%)	Acinetobacter spp (%)
UPTH	7 (4.24)	0 (0.00)
RSUTH	29(17.58)	3(60.00)
MAUTH	18(10.91)	2(40.00)
Total	54 (32.73)	5 (100.00)

Total number of Enterobacteriaceae isolates = 165, while Total number of *Acinetobacter* spp = 5

To confirm the carbapenemase-producing potential, isolates with imipenem inhibition zones $\leq$ 19 mm were regarded as potential carbapenemase producers. Out of 54 Enterobacteriaceae isolates screened, 12 (22.2 %) were MBL-positive and 16 (29.63 %) were KPC-positive (Table 4). The highest rate of MBL-positive Enterobacteriaceae was found in

MAUTH (9.26 %), followed by UPTH (7.41 %) and RSUTH (5.56 %). In *Acinetobacter spp* (n = 5), 100 % of isolates were carbapenemase producers: 3 were MBL positive and 4 were KPC positive. 40 % of KPC-positive *Acinetobacter spp* were found in both RSUTH and MAUTH while MBL positivity was predominant in MAUTH (40 %). Carbapenemase-producing *Acinetobacter spp* was not found in UPTH.

DISCUSSION

A total of 423 pregnant women attending the antenatal clinics of University of Port Harcourt

Teaching Hospital (UPTH), Rivers State University Teaching Hospital (RSUTH), and Madonna University Teaching Hospital (MAUTH) was employed in the study and their frequency showed no statistically significant differences across their characteristic such as population in each hospital facility, age group, gestational age, education level, and parity. Although prior studies on urinary tract infections (UTIs) in pregnancy has identified factors such as age, parity, and gestational age as potential risk determinants [4], no such associations was found in tthis study.

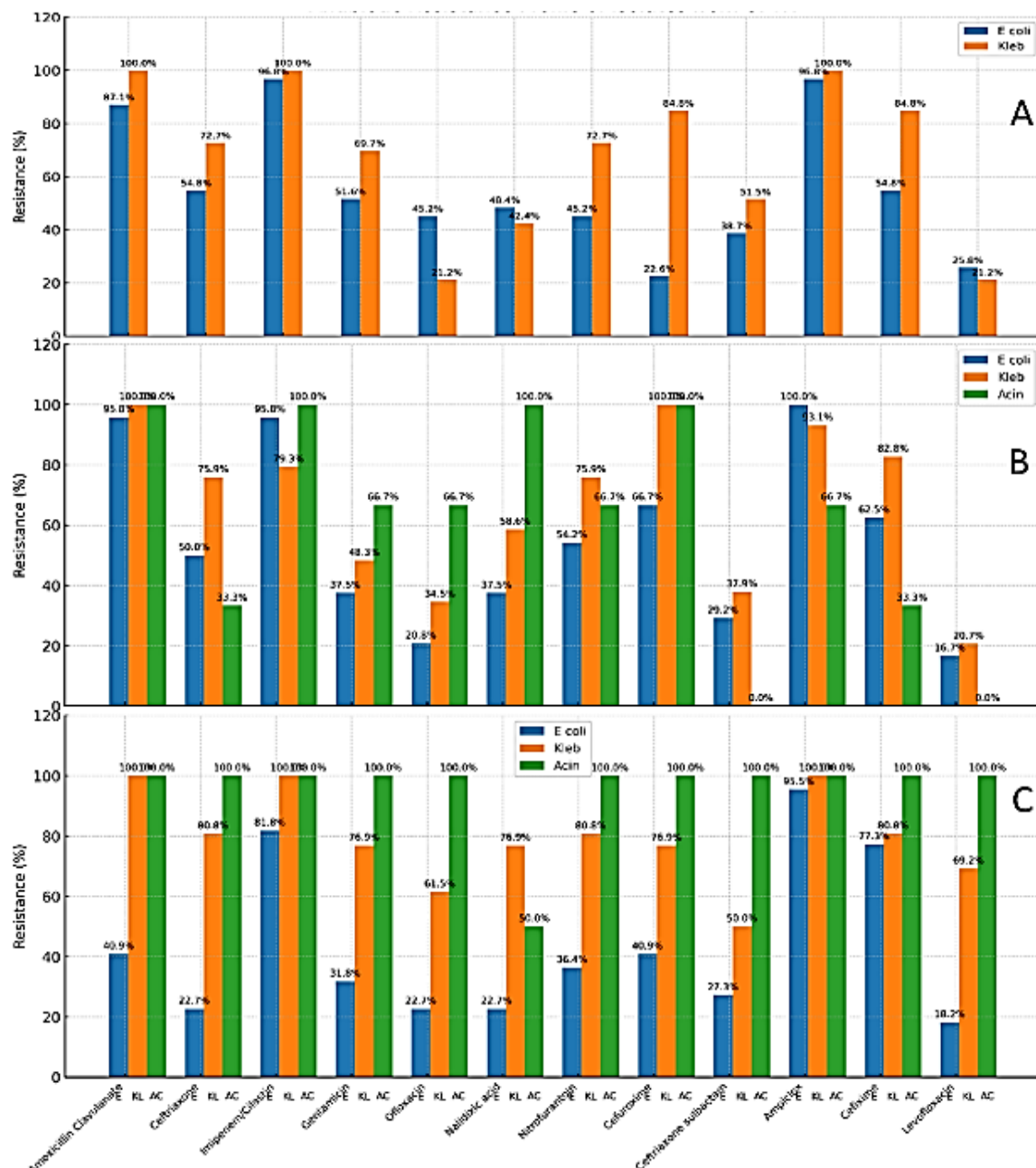


Figure 1: Antibiotic resistance of the isolates from UPTH (A), RSUTH (B) and MUTH (C)

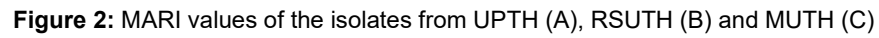


Table 4: Phenotypic Characterisation of MBL and KPC producing isolates

Facility	MBL positive		KPC positive	
	<i>E_{MBL}</i>	<i>A_{MBL}</i>	<i>E_{KPC}</i>	<i>A_{KPC}</i>
UPTH	4(7.41%)	0(0.00%)	3(5.55%)	0(0.00%)
RSUTH	3(5.56%)	1(20.00%)	6(11.11%)	2(40.00%)
MAUTH	5(9.26%)	2(40.00%)	7(12.96%)	2(40.00%)
Total	12(22.59%)	3(80.00%)	16(29.63%)	4(80.00%)

E_{MBL}: Metallobetalactamase Enterobacteriaceae positive; *E_{KPC}*: Enterobacteriaceae *Klebsiella pneumoniae* carbapenemase, *A_{MBL}*: Metallobetalactamase *Acinetobacter species* positive; *A_{KPC}*: *Acinetobacter species Klebsiella pneumoniae* carbapenemase, n = 165 for Enterobacteriaceae, while n = 5 for *Acinetobacter spp*

For instance, the > 40-year age group, which represented 21.0 % of participants, did not show a significantly higher prevalence of bacterial isolates. Furthermore, education level showed no significant association with bacterial isolation, indicating that educational attainment alone did not predict colonisation or infection risk in this setting. Although education level was seen as a determinant of risk of infection in studies on antimicrobial resistance [13], no such effect was seen in this study; this could possibly be a result of uniform exposure irrespective of the educational background.

A total of 170 Gram-negative isolates were obtained, with 165 (97.1 %) Enterobacteriaceae and 5 (2.9 %) *Acinetobacter spp*. The predominance of these bacteria in the genitourinary tract has been reported to be due to the ability of the organisms to adhere to uroepithelial cells and produce virulence factors like biofilms, making them highly effective uropathogens [6]. The low frequency of *Acinetobacter spp* was expected due to the outpatient nature of the study population and the exclusion of participants recently hospitalised, catheterised, or exposed to antibiotics—factors known to encourage the proliferation of *Acinetobacter spp*.

The Enterobacteriaceae *spp* recovery was highest at UPTH (38.8 %), followed by RSUTH (32.1 %) and MAUTH (29.1 %). *Acinetobacter spp* was detected only at RSUTH (60 %) and MAUTH (40 %). These variations may reflect differences in hygiene standards, patient density, or environmental factors [7], though the absence of statistical significance suggests incidental variation. No significant associations were observed between bacterial isolation and demographic factors such as age, gestational age, education, or parity. Enterobacteriaceae were most frequent among women aged > 40 years (39.4 %), while *Acinetobacter spp* occurred most among those aged 21 – 30 and > 40 years (each 40 %). These findings imply that colonisation may occur independently of age-related physiological or behavioural changes.

Similar results, which also found no significant correlations between age or parity and Gram-negative bacterial colonisation among non-hospitalised antenatal women, have been reported [14].

Although late gestational age (28 – 40 weeks) recorded the highest Enterobacteriaceae recovery (38.8 %), this trend was not statistically significant. Hormonal and anatomical changes in late pregnancy may predispose women to transient colonisation, but larger samples or longitudinal designs are required to confirm this relationship [15]. Educational level also showed no significant correlation. The higher number of isolates among tertiary-educated women (42.4 %) likely reflects the greater hospital attendance, while *Acinetobacter spp* were found more among those without formal education (60 %), possibly due to lower hygiene awareness, though this remains speculative. Likewise, parity did not have any significant effect on bacterial isolation. The low rate of isolation of *Acinetobacter spp* further reinforces its status as an opportunistic, mainly hospital-acquired pathogen. The dominance of Enterobacteriaceae emphasises their dual role as commensal and opportunistic pathogen, capable of transiently colonising healthy hosts.

Antimicrobial susceptibility revealed a pattern that shows that *Klebsiella pneumoniae* and *Acinetobacter spp* were the most resistant isolates. These isolates exhibited near-total resistance to β -lactam antibiotics such as amoxicillin-clavulanate, cefuroxime, and ceftriaxone. This concurs with global reports connecting β -lactam resistance in Enterobacteriaceae to extended-spectrum β -lactamase (ESBL) and carbapenemase production [2]. On the contrary, *E. coli* exhibited higher susceptibility to fluoroquinolones (up to 77 %), consistent with earlier reports from Nigeria [16]. This could be attributed to the fact that fluoroquinolones are used less commonly during pregnancy. The occurrence of plasmid-mediated *qnr* genes in fluoroquinolone-resistant *E. coli*

isolates in Nigeria signals a growing threat to this drug class [16].

Gentamicin and nitrofurantoin resistance was moderate in *E. coli* but high in *K. pneumoniae* and *Acinetobacter spp.*, which could be attributed to the action of the aminoglycoside-modifying enzymes and efflux pumps. [17]. The Multiple Antibiotic Resistance Index (MAR_I) ranged from 0.2 to 1.0. An MAR_I above 0.2 indicates exposure to high antibiotic pressure environments [8]. Several isolates were resistant to all tested antibiotics and the elevated indices recorded could be attributed to the indiscriminate antibiotic use in both hospital and community settings.

Carbapenemase production was detected in 32.7 % of Enterobacteriaceae and all *Acinetobacter spp.* This reflects the widespread dissemination of carbapenemase-mediated resistance. The hospital with the highest number of isolates that produced carbapenemase enzyme, as seen in the study, is RSUTH. This could possibly be due to its status as a referral centre with higher antibiotic utilisation. Comparable rates have been documented across Nigeria [10]. Phenotypic screening alone identified 22.2 % of Enterobacteriaceae as metallo- β -lactamase (MBL) producers and 29.6 % as *Klebsiella pneumoniae* carbapenemase (KPC) producers, while 80 % of *Acinetobacter spp.* co-produced both enzymes. The co-production of MBL and KPC enzymes poses major therapeutic challenges, often limiting options to colistin or tigecycline [18]. The detection of such multidrug-resistant and carbapenemase-producing uropathogens in pregnant women is of great concern due to complications that may arise in the pregnancy and newborn. Such complications could include preterm birth, sepsis, and treatment failure.

Limitations of this study

This was a cross-sectional study, hence it could not establish causality. The sample of pregnant women attending the three tertiary hospitals may not be representative of all levels of care and settings. Also, the detection of carbapenemases was based solely on phenotypic methods, which may result in limitations in the precision of detection of the resistance gene. The low number of *Acinetobacter spp.* isolates may also limit subgroup analyses, and the lack of detailed clinical information on the subjects, such as their history of antibiotics and pregnancy outcomes, may have limited the assessment of risk factors. Finally, the determination of the susceptibility of the bacteria was based only on disc diffusion,

which may have limited the assessment of critical antibiotics.

CONCLUSION

The predominance of *Enterobacteriaceae* and the rarity of *Acinetobacter spp.* supports the claim that Enterobacteriaceae exist to confirm the asymptomatic flora and supports *Acinetobacter spp.*'s hospital-associated nature. There are no significant correlations between bacterial isolates and demographic or obstetric factors; hence, the presence of bacteria may be independent of socio-demographic factors. High levels of resistance, especially to β -lactam antibiotics among *K. pneumoniae* and *Acinetobacter spp.*, and the presence of carbapenemase-producing bacteria, including KPC and MBL, suggest alarming trends of antimicrobial resistance. The production of KPC and MBL carbapenemases among *Acinetobacter spp.* suggests the potential of horizontal gene transfer. The resistance indices of > 0.2 suggest that the isolates have been exposed to environments where there was pressure from antibiotics, validating previous studies from Nigeria that have related resistance to the indiscriminate use of antibiotics.

DECLARATIONS

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Ethical approval

Ethical approval was obtained from the Research Ethics Committees of the participating Hospitals (UPT/ADM/90/S.II/VOLXI/1718; MAU/DRC/HD/E/2024/008; and NHREC/21/033/2022).

Use of Artificial intelligence/Large language models

The authors confirm that AI-based tools were used solely for language editing and manuscript polishing purposes (e.g., grammar, phrasing, and clarity). No AI tools were used to generate content, interpret data, or influence study design, results, or conclusions. All intellectual contributions, study analyses, and interpretations reported in the manuscript are the original work of the authors.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

No conflict of interest is associated with this work.

Contribution of authors

We declare that this work was done by the author(s) named in this article, and all liabilities pertaining to claims relating to the content of this article will be borne by the authors.

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